Use Data To Show You've Made A Maintenance Improvement

Crow/AMSAA (C/A) plots are log-log plots from the field of reliability for showing you've made improvements and reduced failures. Its show me, don't tell me, technology for handling a variety of data. You'll also see the name spelled as Crow-AMSAA (C-A) plots.

Two plots are used with C/A analysis:

- **The first plot** is a simple cumulative failures on the vertical Y-axis and cumulative time on the horizontal X-axis. This plot always climbs from the lower left hand corner of the plot towards the upper right hand corner as both time and failures accumulate.
- **The second plot** is derived from the first plot by transforming the Y-axis into cumulative MTBF by dividing the cumulative failures into the cumulative time. The MTBF plot goes up and to the right with improvements, or it goes down and to the right with increasing failure rates.

Remember our task as reliability engineers is to **put** a flattening cusp on the cumulative failures versus cumulative time trend line so that failures come more slowly. Deciding about the cusps is a subject for engineering judgment.

C/A methodology does not have the strict data requirements demanded for Weibull plots. For example, Weibull plots require:

1. Weibull age-to-failure data requires knowing the age from time = 0 where time commences, up to the age at failure, for a human example, this means knowing the date of birth and the date of death to get the age-to-failure, and
2. Weibull plots require only a single failure mode for each Weibull plot (excluding mixture analysis techniques).

Weibull analysis provides a simple statistic for components which infers the mode of failure ($\beta<1$ for infant mortality, $\beta>1$ for wear out, and $\beta\approx1$ for random failures). Weibull analysis also gives a single value for describing the characteristic value at failure (η) for the skewed distributions. These statistics provide important clues for corrective actions or coping with expected failures because you will know **how** the failures occur and **when** the failures are expected. Strict data requirements for Weibull plots provide very smart Weibull results but they carry heavy demands for data recording.

Whereas C/A plots provide good information as:

1. C/A plots can tolerate an arbitrary starting point for accumulation of time as you are not forced to zero time,
2. Mixed failure modes are acceptable for analysis which will provide a statistic to tell if failures are increasing ($\beta>1$), decreasing ($\beta<1$), or neither increasing/decreasing ($\beta\approx1$). Mixed failure modes push the C-A analysis, and
3. The visually simple method of extrapolation provides visual evidence of forecasts for future failures.

Data can be entered directly into WinSMITH Visual (WSV) or can be easily imported from Excel worksheets with a simple copy/past command. The data are about time and failure events. Consider the raw failure data shown in Figure 1.

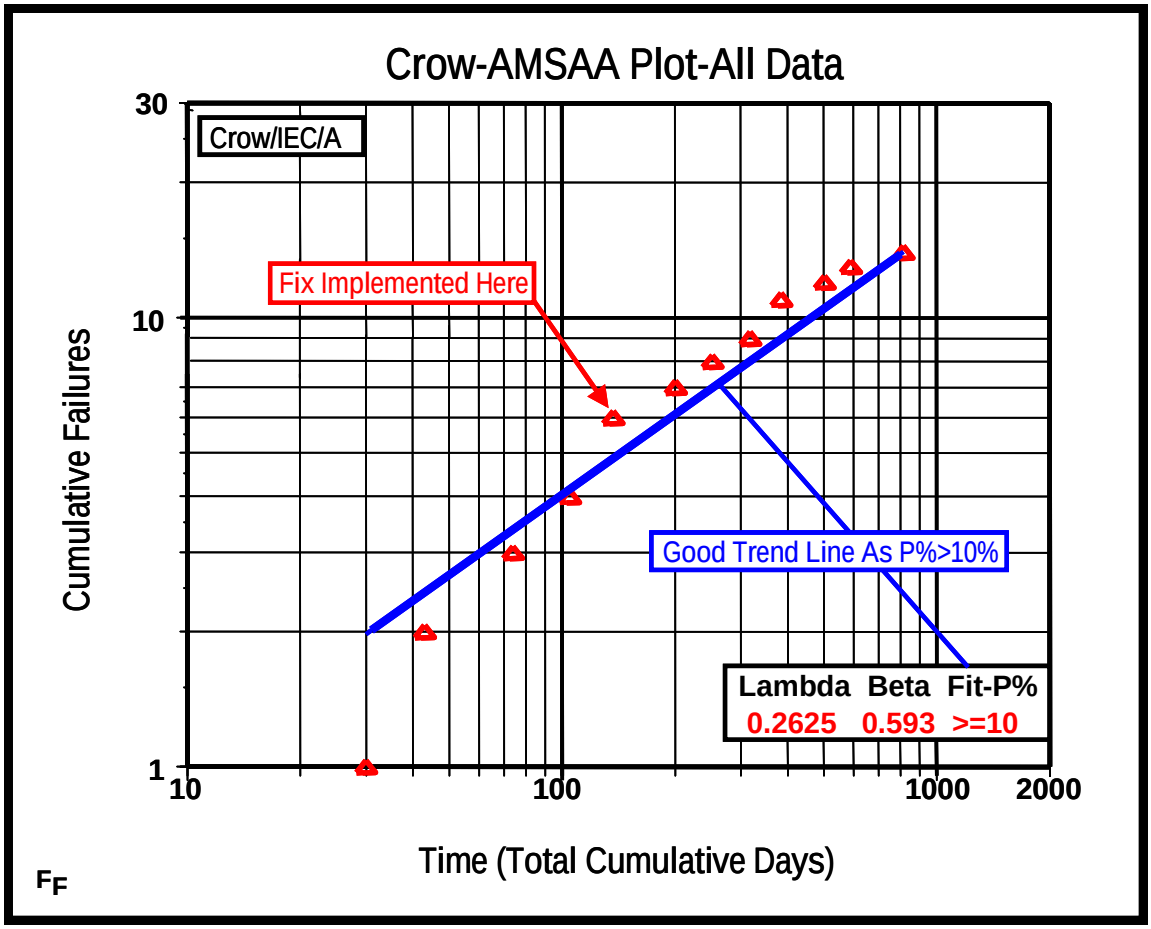
Figure 1-The Data

Raw Data			Paste Into WSV	
Event	Failure Date	Failures Recorded	Cum Days	Cum Failures
1	17-Apr-01	Start	-	-
2	17-May-01	1	30	1
3	30-May-01	1	43	2
4	30-Jun-01	1	74	3
5	31-Jul-01	1	105	4
6	1-Sep-01	2	137	6
7	4-Nov-01	1	201	7
8	25-Dec-01	1	252	8
9	1-Mar-02	1	318	9
10	7-May-02	2	385	11
11	1-Sep-02	1	502	12
12	28-Nov-02	1	590	13
13	12-Jul-03	1	816	14

Sept. 1, 2001 is a red letter date representing the initiation of a fix to permanently avoid a failure mode by using improved maintenance methods.

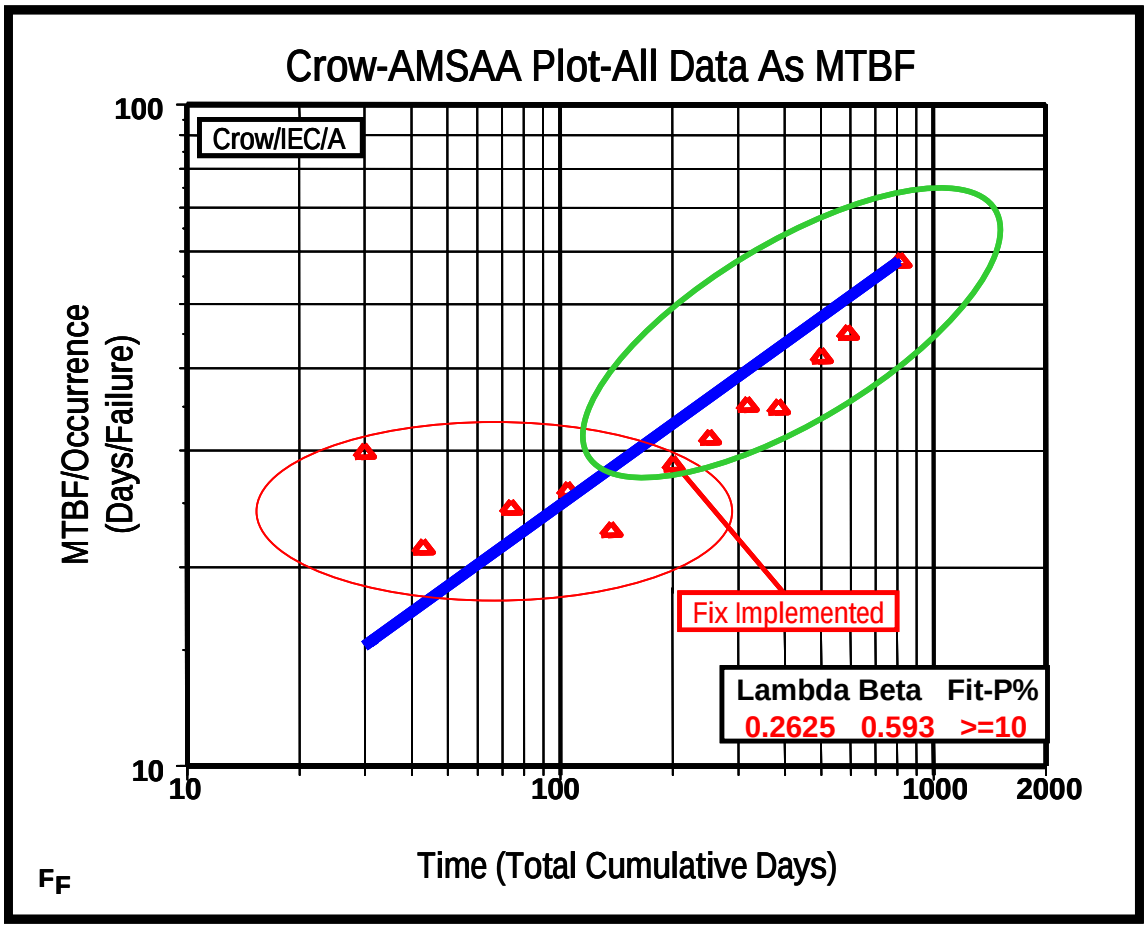
Did we get an improvement? How many failures have we avoided?

Figure 2-Crow/AMSAA Plot-Cum Failures vs Cum Time



The C/A plot in Figure 2 shows a long term improvements (β<1) with a good curve fit. Do we have an improvement cusp at failure 6? The cusp is more visible on the MTBF plot in Figure 3. Figure 3 clearly shows improvements in the mean time between failures that is not so obvious in the trend line of Figure 2 although the statistic in Figure 2 (beta = 0.593) shows big improvements.

Figure 3-Crow/AMSAA Plot-Cum MTBF vs Cum Time



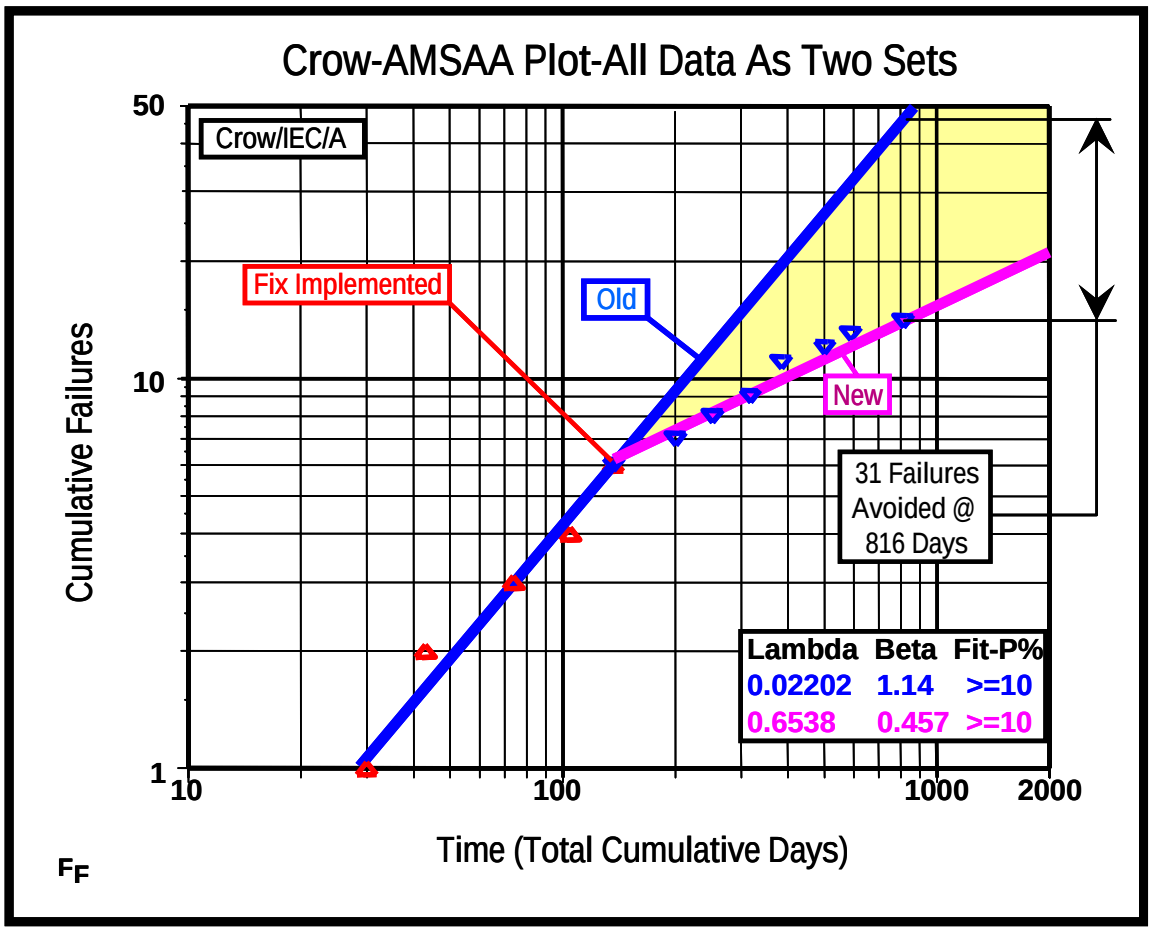
Use good engineering judgment. Split the data from Figure 1 into old data and new data as shown in Figure 4. It seems to work better if you maintain a common data point in each set as the turning point.

Figure 4-The Data Group For Old And New

Raw Data			Paste Into WSV		Paste Into WSV	
Event	Failure Date	Failures Recorded	Cum Days	Cum Failures	Cum Days	Cum Failures
1	17-Apr-01	Start	-	-	New Data	
2	17-May-01	1	30	1		
3	30-May-01	1	43	2		
4	30-Jun-01	1	74	3		
5	31-Jul-01	1	105	4		
6	1-Sep-01	2	137	6	137	6
7	4-Nov-01	1	Old Data		201	7
8	25-Dec-01	1			252	8
9	1-Mar-02	1			318	9
10	7-May-02	2			385	11
11	1-Sep-02	1			502	12
12	28-Nov-02	1			590	13
13	12-Jul-03	1			816	14

Put the two data sets into a new WinSMITH Visual plot as shown in Figure 5. Extrapolate the old and new lines. Find the vertical gap between new and old at 816 days. The gap is clear in Figure 5. It shows 31 failures have been avoided (at 816 days: 45.9 old-14 new = 31 rounding down) with the new procedure. Crow/AMSAA plots provide strong, graphical, evidence for management that the new maintenance methods are demonstrating improvements by reducing failures. Figure 5 uses the data to show you've made improvements.

Figure 5-Crow/AMSAA Plot Of Old And New Data



When will the next failure occur? WSV forecasts the next failure on the new trend line as 133 days into the future at 949 cum days.

Some will be skeptical if the beta value for the new data set truly indicates improvement. WSV's report option shows with 90% confidence, the new β=0.457 lies between 0.188 and 0.726 which gives solid evidence for decreasing failures as β<1 indicating future failures are coming more slowly.

Crow/AMSAA methods are simple tools with strong results using failure data from your maintenance records.

This page is described in terse format in WeibullNews Issue 18. Other Crow/AMSAA details are available at the November 2002 and January 2004 problems of the month. More details are available in The New Weibull Handbook about reliability growth plots.

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Refer to the caveats on the **Problem Of The Month Page** about the limitations of the solution above. Maybe you have a better idea on how to solve the problem. Maybe you find where I've screwed-up the solution and you can point out my errors as you check my calculations. E-mail your comments, criticism, and corrections to: Paul Barringer by  **clicking here**. Return to the top of this problem.

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